Sayh al Uhaymir 169

Basalt-bearing anorthositic regolith breccia

206.45 g

Figure 1: Sayh al Uhaymir 169 as found in the Oman desert January 16, 2002.

Introduction

SaU169 is a complete, light grey-greenish rounded stone (7.0 × 4.3 × 4.0 cm) weighing 206.45 g, and found in the Sayh al Uhaymir region of Oman (Figs 1 and 2). Dark brown fusion crust is only locally preserved. Impact melt breccia comprises 87 vol% of the stone, and contains 25–40 vol% of strongly shocked noritic and granulitic clasts (up to 17 mm) and fragments, set in a fine-grained (<0.1 mm) crystalline matrix (Fig. 3). Most crystal fragments are shocked plagioclases, locally associated with enstatite. Minor amounts of metallic iron, spinel, olivine, and orthopyroxene clasts are also present. The K/U = 553, Fe/Mn of 75.1, and oxygen isotope composition of $\Delta^{17}O = 0.001 \pm 0.032‰$, all indicate a lunar origin.

Petrography and mineralogy

The fine-grained impact melt matrix consists mainly of short prismatic low-Ca pyroxene ($En_{61–64}$, $Wo_{2–4}$), interstitial plagioclase ($An_{75–81}$) intergrown with potassium feldspar. The remaining minerals are poikilitic ilmenite, whitlockite, olivine ($Fo_{58–59}$), zircon, and

traces of troilite, kamacite and tridymite. The regolith (13 vol%) present on one side of the meteorite comprises crystalline and glassy volcanic rocks, igneous lithic fragments, breccia fragments, fragments of mafic granulites, and crystal fragments.

Figure 2: Complete stone of SaU169 showing the fusion crust and also a large clast.

Figure 3: Cut slab of SaU169 illustrating the impact melt breccia (light tan, below) and the regolith breccia (dark brown, above).

Chemistry

SaU169 is very similar in composition to Apollo KREEP impact melt breccias, but has slightly lower Al and Si, and higher Na, Ti and P (Gnos et al., 2003, 2004; Table 1). The impact melt breccia contains 32.7 ppm Th and 8.6 ppm U, 0.47% K, and 1332 ppm total REE, indicating it is more enriched in KREEP elements than any other known lunar rock (Fig. 4, 5 and 6). Th and Sm are higher than all mare and highlands lunar meteorites, and similar to KREEP (Fig. 4). And SaU169 stands alone as an unusual composition of mingled breccia, having intermediate Al_2O_3 like others such as Calcalong Creek, and Yamato 983885, but much higher Th (Fig. 4). Mafic impact melt breccias from Apollo 12 and 14 are close compositionally to the SaU169 impact melt breccia (Fig. 5; Zeigler et al., 2006), and more detailed studies and comparisons of these samples will undoubtedly led to a better understanding of this unusual meteorite. In comparison, the average regolith (Table 1) is similar in composition to Apollo 12, 14 and 15 regoliths, but is not depleted in Na and K. The regolith clast is also KREEP related, but not directly related to the impact melt because it has a higher K/U ratio (1253).

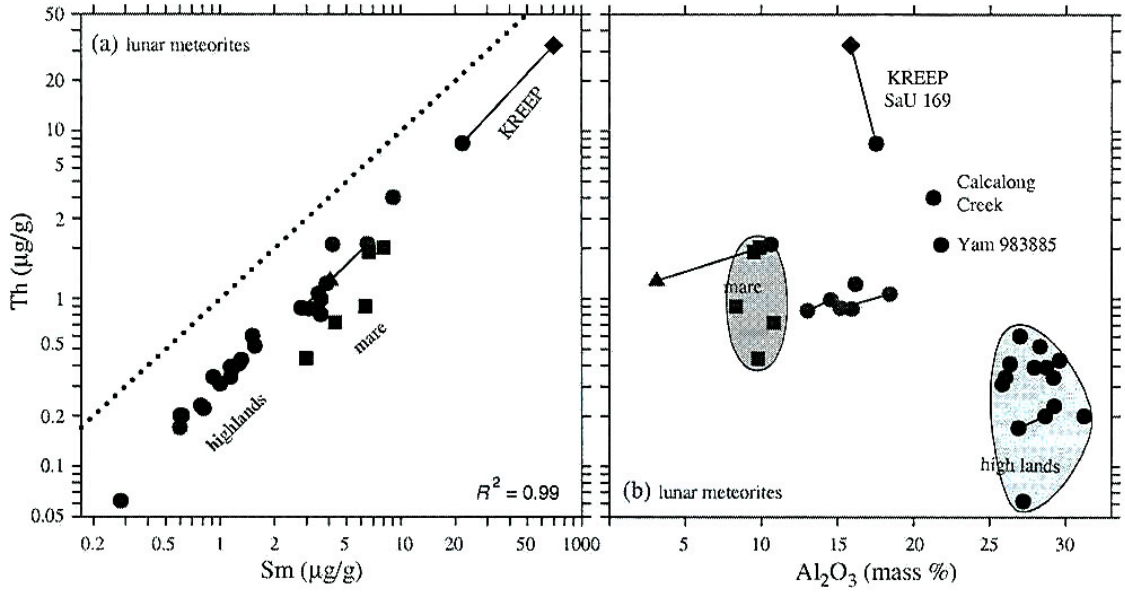
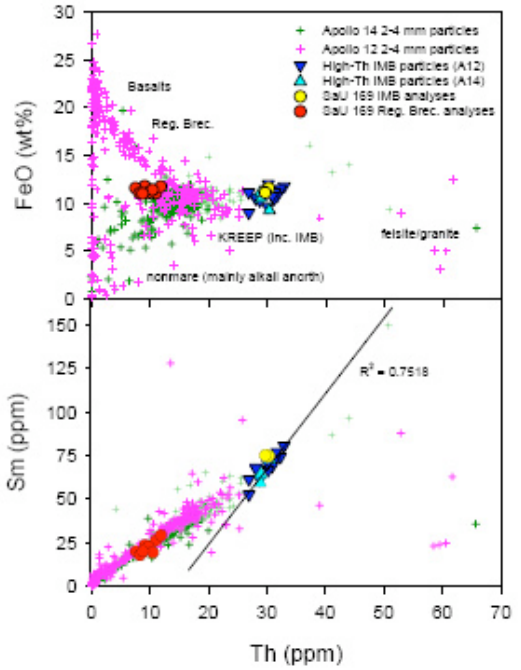


Figure 4: Th-Sm-Al_2O_3 systematics of SaU169 compared to mare, highlands, Calcalong Creek and KREEP samples (from Korotev, 2005).



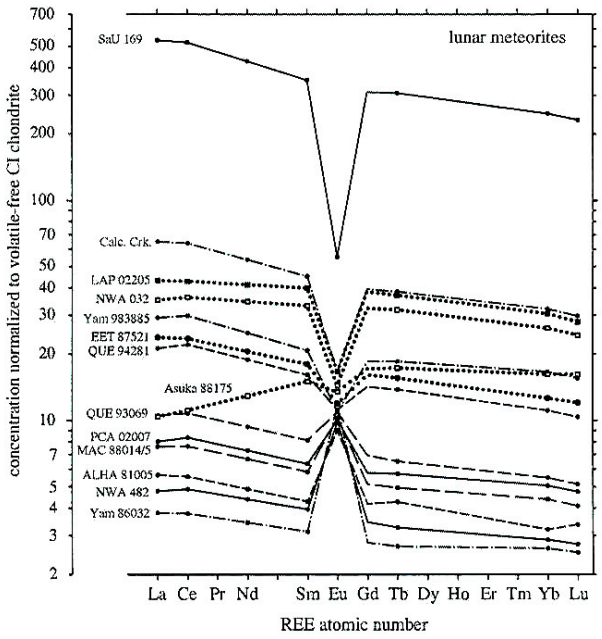


Figure 5 (left): Comparison of SaU169 analyses with those from impact melt breccias from the Apollo 12 and 14 collections (from Zeigler et al., 2006).
Figure 6 (right): REE pattern for SaU169 illustrating its high concentrations of REE compared to all other lunar meteorites (from Korotev, 2005).

Radiometric age dating

^{39}Ar-^{40}Ar dating of feldspar concentrates from SaU169 yielded a 2800 Ma age, suggesting a resetting event at this time. ^{207}Pb-^{206}Pb isotope ratios were measured on 12 different impact melt zircons and yielded a weighted average age of 3909 Ma (Fig. 7). This age is similar to the age proposed for the Imbrium impact event, and together with the KREEP-rich nature of SaU169 has led Gnos et al. (2004) to propose an origin near the Procellarum KREEP Terrane.

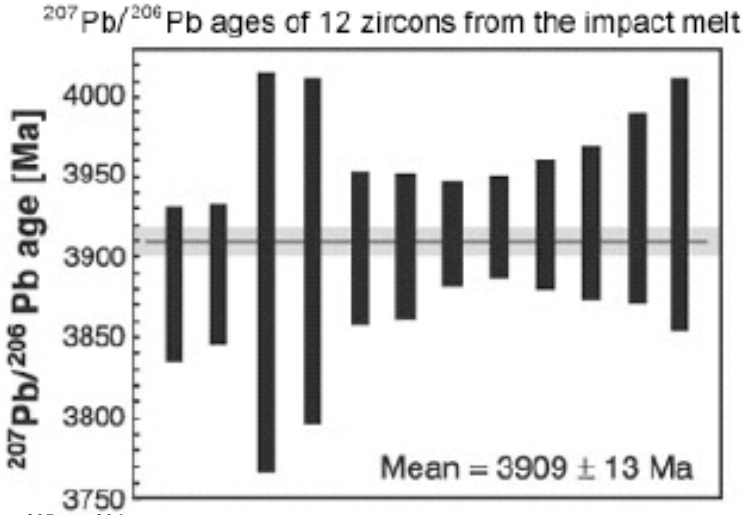


Figure 7: results of ^{207}Pb/^{206}Pb dating of 12 zircon grains from the impact melt (from Gnos et al., 2004).

Cosmogenic isotopes

Cosmogenic isotope studies of SaU169 have yielded ^{21}Ne and ^{38}Ar lunar surface exposure ages of 150 to 200 Ma (Gnos et al., 2004). ^{10}Be measurements indicate a short transfer time of < 0.234 Ma, and a terrestrial age of < 9700 yrs. was found using ^{14}C and ^{10}Be (Gnos et al., 2004).

Table 1a. Chemical composition of SaU169

reference	1	1	1
weight	827	185	117
method	a,b,e	a,b	a,b
SiO_2 %	45.15	46.9	
TiO_2	2.21	2.49	1.47
Al_2O_3	15.88	17.54	16.34
FeO	10.67	11.09	8.8
MnO	0.14	0.14	0.12
MgO	11.09	7.94	6.92
CaO	10.16	11.72	10.6
Na_2O	0.98	0.78	1.18
K_2O	0.54	0.46	0.88
P_2O_5	1.14	0.42	0.76
S %	0.33		
sum			
Sc ppm	25	28	18
V	36	61	36
Cr	992	1310	811
Co	31	19	12
Ni	204	82	58
Cu	9	<20	<20
Zn	31	<60	<60
Ga			
Ge			
As			
Se			
Rb	13.7	10	20
Sr	359	214	230
Y	532	162.5	338
Zr	2835	596	1397
Nb	124	18	112
Mo			
Ru			
Rh			
Pd ppb			
Ag ppb			
Cd ppb			
In ppb			
Sn ppb			

Sb ppb			
Te ppb			
Cs ppm	0.8	0.4	0.9
Ba	1520	593	1351
La	170	52	113
Ce	427	139	297
Pr	57.45	17.1	35.6
Nd	256.5	76.9	162
Sm	70.15	21.9	44.9
Eu	4.2	2.43	2.45
Gd	86.4	25.3	50.4
Tb	15.1	5.08	10.5
Dy	94.15	30.7	63.9
Ho	21.3	6.36	13
Er	58.05	18.6	39.3
Tm	9.13	2.72	5.96
Yb	54.65	16.9	36
Lu	7.64	2.53	5.24
Hf	64.3	14.8	34.7
Ta	7.1	2.14	4.16
W ppb	3450	1300	2500
Re ppb			
Os ppb			
Ir ppb	4.2		
Pt ppb			
Au ppb	6		
Th ppm	32.7	8.44	21.7
U ppm	8.6	2.27	5.83

technique (a) ICP-AES, (b) ICP-MS, (c) IDMS, (d) Ar, (e) INAA

Table 1b: Volatile element composition of SaU169

Li ppm			
Be			
C			
S			
F ppm			
Cl			
Br			
I			
Pb ppm	13.8	<10	<10
Hg ppb			
Tl			
Bi			

1) Gnos et al. (2004) three columns are impact melt breccia, average regolith and KREEP clast, respectively